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# Development of a Tractor Drawn Turmeric Planter

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## ABSTRACT

*Planting of turmeric has been a challenge to the farmers in Nigeria due to the absence of planting machine. The farmers are left to the traditional method of planting with hoes and cutlasses. This method is time consuming, labour intensive, associated with human drudgery and a high demand for human energy. As a result, a mechanical planter was designed and fabricated. The main objective of the study is to develop and evaluate the performance of a tractor- drawn turmeric planter. The planter was designed, fabricated and tested in the Agricultural and Bioresources Department of The Federal University of Technology, Minna. It consists of a ground drive wheel, hopper, metering system furrow opener, residue cutting edge, furrow closing device press wheel and power transmission mechanism. The performance tests of the fabricated machine were carried out using three levels of turmeric rhizome lengths (30 mm, 45 mm and 60 mm) at three levels of operational speeds (8km/h 10km/h and 12km/h). The results revealed that there was no steady pattern in the increase or decrease of miss index with increase in turmeric rhizome length and machine operational speed. The highest percentage turmeric rhizome miss index of 35% was recorded for turmeric rhizome length of 30cm at machine operational speed of 10km/h whereas the lowest percentage turmeric rhizome miss index of 15% was obtained for turmeric rhizome length of 60cm at the machine operational speed of 12km/h. The machine operational speed and size of the turmeric rhizomes affect the field capacity of the machine. The highest capacity of 0.96ha/h was recorded at the highest operational speed of 12km/h. The lowest field capacity of 0.63ha/h was recorded at the lowest machine speed of 8km/h. The developed machine could reduce drudgery involved in manual turmeric planting and save about substantial amount of labour and operating time.*

**Keywords:** *Development, testing, tractor-drawn turmeric, planter*

## INTRODUCTION

Turmeric (Curcuma longa linn) is a stem tuber crop. It belongs to the same family as ginger (Zingiberaceae) and grows in the same hot and humid tropical climate. The rhizome is deep bright yellow in colour. Turmeric was derived from Latin word terra merita (merited earth). In Nigeria, turmeric is cultivated mostly on subsistent bases in about 19 states (Nwaekpe*et al.*, 2015). The underground rhizome impacts a distinctive flovour to food but it is also used to provide food with a deep indelible orange colour (FAO, 2004). Modern medicine has begun to recognize its importance, as indicated by the over 3000 publications dealing with turmeric that came out within the last 25 years (Sahdeo and Bharat, 2011).

Nutritional analysis showed that 100 g of turmeric contains 390 kcal, 10 g total fat, 3 g saturated fat, 0 mg cholesterol, 0.2 g calcium, 0.26 g phosphorous, 10 mg sodium, 2500 mg potassium, 47.5 mg iron, 0.9 mg thiamine, 0.19 mg riboflavin, 4.8 mg niacin, 50 mg ascorbic acid, 69.9 g total carbohydrates, 21 g dietary fiber, 3 g sugars, and 8 g protein (Balakrishnan, 2007;Sahdeo and Bharat, 2011). Planting of turmeric has been a challenge to the farmers in Nigeria due to the absence of planting machine.

The farmers are left to the traditional method of planting with hoes and cutlasses. This method is time consuming, labour intensive, associated with human drudgery and a high demand for human energy. It was noted that "time is the essence of farming" and whatever help shorten the time required for planting will help overcome the effect of adverse weather (Ajitet al., 2006). To achieve food security through large scale production (Mechanization) of crops with high potentials/prospects such as turmeric, there is much need to provide a planting aid to Nigerian farmers to alleviate their suffering. The recent climatic change which results in delayed early rain and short duration of annual rainfall affects the maturity of the turmeric rhizomes due to the long-time taken in manual planting of turmeric. In most cases, turmeric do not attain 7 – 9 months maturity before the end of the rainy season due to the delay as a result of time (duration) spent in the use of manual planting method. With the above stated reasons, the development of a tractor drawn turmeric planter became necessary. The developed implement is expected to improve the timeliness and efficiency of operation as well as reduce drudgery and cost of turmeric production. The aim of this research work therefore, is to develop a tractor-drawn turmeric planter.

## MATERIAL AND METHODS

### Design Analysis

The following design analyses were carried out to determine and select the various machine parts:

#### Determination of the Minimum Width of Planter

The minimum width of the planter required to cover 8 hectares per day at operational speed of 10km/h was estimated using equation 1as follows:

$$C_T = v \times w \qquad (1)$$

Where $C_T$ = theoretical capacity, with operational time of 8 hours in a day ($m^2$/h)

S = speed of operation (m/h)

w = implement working width (m)

#### Determination of Hopper Dimensions and Capacity

The hopper was designed to feed the metering device in vertical direction. The shape, location and dimensions of the hopper were selected to ensure free flow of the cane seed. To achieve this, static coefficient of friction was determined. The coefficient of friction was found to be 0.47. The dimension of hopper was chosen to avoid frequent loading of the hopper. It has a shape of trapezoidal shape as shown in (Figure 3.9) below.

Based on the above stated parameters the volume of hopper was estimated using Equation 2 given by Olaoye and Bolufawi (2001) as follows:

$$V = \frac{S_R}{n \times BD} \qquad (2)$$

Where V = volume of the hopper ($m^3$)

$S_R$ = seeding rate of turmeric rhizome (kg/h)

n = number of refilling per hectare

BD = bulk density kg/$m^3$

#### Design of Rhizome Seed Metering Device

Proper design of the metering device by calculating the number of holes in the metering devise is an essential element for satisfactory performance of the planter. It was designed to distribute seeds uniformly at the desired application rate and control seed spacing. Hence, the number of holes on the metering device was determined as reported by Khan *et al.* (2015), as follows:

$$N_g = \frac{\pi D_w}{i \times x} \qquad (3)$$

Where: $D_w$= diameter of the drive wheel

i = drive ratio

x = intra raw spacing (m)

#### Determination of the Angular Speed of the Drive Wheels (Rpm)

The drive wheels of the planter transmit power to the metering mechanism of the planter through chain drive arrangement. The angular speed of drive wheel which is the same as the angular speed of the smaller sprocket is essential in the design of chain and sprockets as well as estimating power transmission through chain drive.

The angular speed of the drive wheels of the planter was estimated using Equation 4 (Maxmillan, 2002)

$$V = \pi D N_w \qquad (4)$$

Where V =operational speed (m/h)

D = diameter of drive wheel (0.6m)

Nw= rotational speed of drive wheel (rpm)

#### Determination of the Shear Strength of the Planters Drive Wheels

This was determined in other to select materials of appropriate thickness for the wheel thereby avoiding failure by crumbling. The following equation as reported by Thomas and Brown (2005) was used to analyse the shear strength of the drive wheel.

$$\tau = \frac{T}{2A\, t_w} \qquad (5)$$

Where: $\tau$ = shear strength of the wheel

T = the torque provided by the wheel (N/m)

A = area of the wheel based on the median diameter of the wheel ($m^2$)

$t_w$ = thickness of the wheel (m)

r = the outer radius of the wheel (m)

## Determination of the Torque of the Planter's Wheel

The torque of the planter's wheel is essential in estimating the power that is transmitted to the metering shaft and in determining the minimum size of diameter required for both the wheel shaft and metering device shaft. It was obtained using Equation 6 as reported by Khan *et al.*, (2015)

$$T_w = K_w \times W_w \times R_w \qquad (6)$$

Where: $T_w$ = torque of the wheel

$K_w$ = rolling resistance coefficient of wheel (0.3 for metallic wheel)

$W_p$ = Weight on the drive wheel

$R_w$ = Radius of the wheel

## Determination of the Diametre of Wheel Shaft and Metering Device Shaft

The size of the wheel and metering device shafts to transmit power from drive wheel to the metering device is dependent on the twisting moment (torque) and the maximum bending moment on the shafts as well as the allowable stress of the material of make of the shaft. The minimum shaft diameter is obtained from the following relationship reported by khurmi and Gupta (2007)

$$d^3 = \frac{16}{S_a \pi}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (7)$$

Where: d = diameter of shaft (m)

S = allowable shear stress ($40 \times 10^6$ $Nm^2$ for shaft with key way)

$K_b$ = combined shock and fatigue factor applied to bending moment

$K_t$ = combined shock and fatigue factor applied to twisting moment

$M_b$ = maximum bending moment

$M_t$ = twisting moment (196.12Nm)

## Determination of the Implement Draft

Draft is an important factor in determining implement power requirement. According to ASAE (1999), average draft requirements can be estimated using Equation 8:

$$D_I = F_i(A+Bv+Cv^2)\, wd \pm R \qquad (8)$$

Where: $D_I$ = implement draft, N

$F_i$ = dimensionless texture adjustment factor

i = 1 for fine, 2 for medium and 3 for coarse texture soils

A, B and C = implement specific constants

v = travel speed, km/h

w = implement working width, (m)

d = tillage depth, cm (1.0 for minor tillage tools and seeders)

R = range of power requirement due to differences in machine design, machine adjustment and crop conditions.

But w = inter row spacing × number of rows

From ASAE standards, following are the values: (for row crop planter which are drawn type but seeding only)

$F_1 = F_2 = F_3 = 1.0$, $A = 900$, $B = C = 0.0$, $v = 10.0$ km/h, $w = 1.0 \times 2 = 2.0$m, $d = 1.0$ for seeders and $R = 25\%$

## Determination of Power Requirement of the Implement

Power transmitted through the drive wheel is essential in the designing of the chain drive arrangement. This to ensure that the torque generated will be able to move the metering mechanism. This was obtained using equation 9 as reported by Khurmi and Gupta (2007).

$$p_w = \frac{2\pi N_w T_w}{60} \qquad (9)$$

Where: Pw = power transmitted through the wheel (W)

Nw= speed of the wheel (rpm)

Tw= torque of the wheel (Nm)

## Description of the Machine

### *Machine Frame*

This is the skeletal structure of the planter on which all other components are mounted. It was constructed from 75 mm x 75 mm x 6 mm carbon steel angle iron. Provisions are made for the 3-point hitching linkages for tractor connection to the machine. During road transportation and on displacement from one field to another, the whole frame is fully mounted on the tractor but during planting operation the planters frame is supported by drive wheel. The structure of frame is as shown in the Figure1

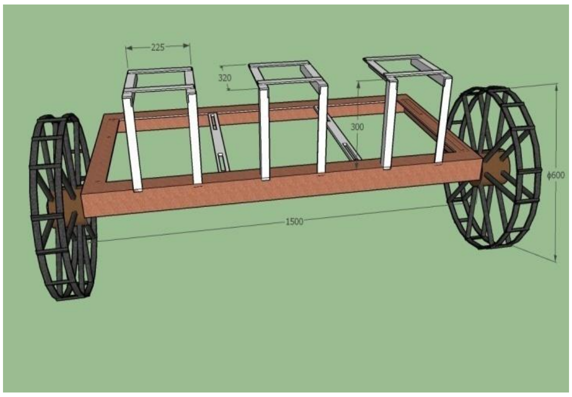

**Figure1.** *Machine frame*

### *Hopper*

The cane seed hopper was made from 1.5 mm thick mild steel sheet. It has a trapezoidal shape (340mm x 340mm) top and (70mm x 40mm) lower end. A rubber seal was fixed round the lower end to avoid bruising the rhizomes. It also reduced friction between the rotating metering device and the edge of the hopper and holds the turmeric rhizomes temporarily for planting as the machine is drawn along on the field. The hopper is as shown in figure 2.

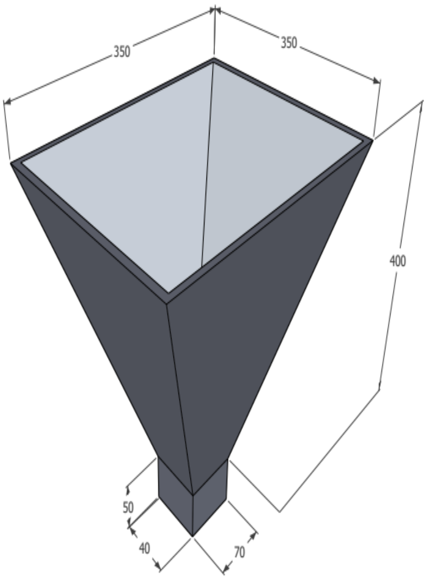

**Figure2**. *Hopper*

### *Metering Device*

This was constructed in a circular disc. The circular disc has six grooves of 70mm x 60mm x 50mm. The disc is slightly touching the hopper standing vertically above the metering device. This is to ensure that the rhizomes falls into the grooves of the metering system. The power generated by the ground wheel rotates the metering system through a chain transmission. The metering disc on rotation drops the rhizome into the delivering system. The metering device is as shown figure 3

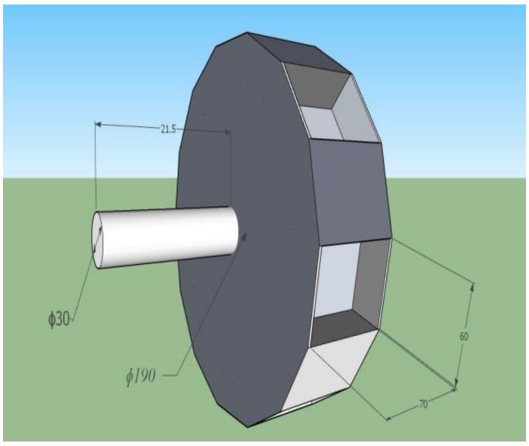

**Figure3.** *Metering Mechanism*

### *Delivery System*

The delivering system is as shown in figure 4, its upper part was made of flat stainless plate curved in a frustum shape. The upper end of the plate was fastened to the frame and passed through under the metering system. The lower end of the flat plate was fastened into a 3 inches PVC pipe. The 400mm length PVC terminated behind the furrow opener and was suspended by a circular metallic ring formed with 8mm rod. The delivering channel is as shown in figure 4.

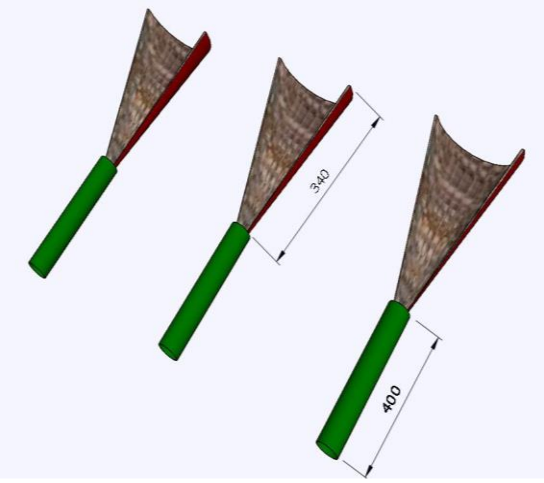

**Figure4.** *Delivery funnel*

### *Furrow Opener*

the furrow opener of this planter is adjustable point type as shown in figure 5. The adjustment was provided to ensure control of 5 – 10cm planting depth as recommended in the agronomic practice of turmeric production. It was made from 8mm thick mild steel flat bar and has horizontal V shape with a sharp edge attached to serve as residue cutting device. The V shape of the furrow opener prevents soil from falling back into created furrow. It creates furrow before the turmeric rhizome is discharged from the delivery channel. It is fastened to the machine frame using 17mm size standard bolts and nuts.

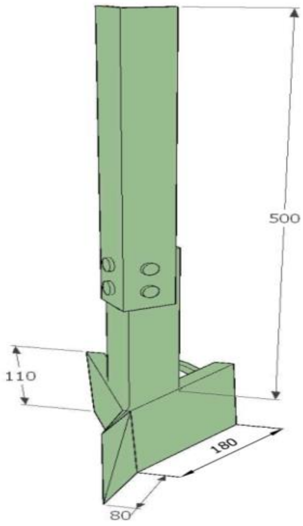

**Figure5.** *Furrow opener*

## *Furrow Closing Device*

The furrow closing device was designed from a 6mm thick mild steel flat bar to form an expanded horizontal U – shape as shown figure 3.4. A 6mm thick mild steel angular bar with holes at the lower end for height adjustments was braced perpendicular to the planter frame downward. A similar angular bar was braced to the U – shape closing deviceand fastened to the perpendicular angular bar with bolts and nuts.

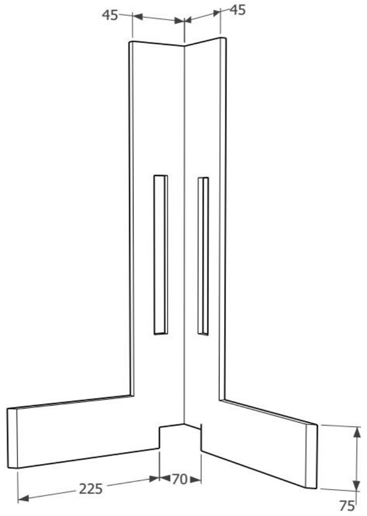

**Figure6.** *Furrow Closing device*

## *The Press Wheel*

The press wheel was constructed in the shape of a car rim. The diameter of the wheel is 200mm with the two-edge rolling on the ground while the center curve inward. The inward curved was designed to allow some quantity of soil to be packed and pressed on top of the turmeric rhizome for good sprouting. It also ensures that the air spaces around the seed inside the soil are covered. The press wheel is shown in figure 7

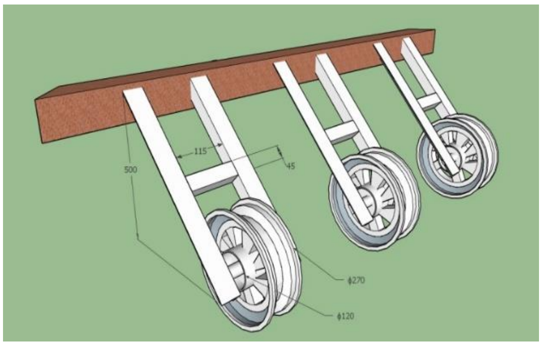

**Figure7.** *Press wheel*

## *Ground Drive Wheel*

T Wheels of larger diameters are to reduce rolling resistance especially in the case of traction wheels(Bharat and Sidharth 2014; Ani et al 2016).The circumference of the drive wheel was formed with 12mm mild steel rod as shown in figure 3.6. An angular mild steel bar of 4mm was used to brace the two circular flat bar at an intervals of 50mm round the drive wheel. A 12mm rod was used to design the spokes. These spokes are used to support the center bushing or hub. The spokes are arranged in such a way that they braced the circular circumference and also give it necessary radial support. The two wheels are connected to the two shafts which are suspended in two sets of bearing. The wheels transmit power obtained by the pull from the tractor.

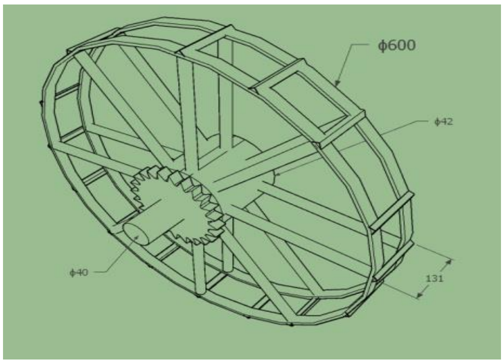

**Figure8.** *Ground wheel*

## *Power Transmission System*

The power transmission system (figure 3.9) performs the work of reducing the ground speed of the tractor to a permissible level that is suitable for the operation of the turmeric rhizome metering system. It is comprised of chain and two sprockets of predetermined sizes. A big sprocket (42 teeth) fitted to the shaft of the drive wheel and a smaller one (15 teeth) connected to the shaft that was fastened to the frame of the planter with two pillow bearings. From that point, power was taken to the metering device shaft with the aid of chain and two sprockets (34 teeth). Chain and sprockets are used to transmit power in the drive so as to prevent power loss during transmission.

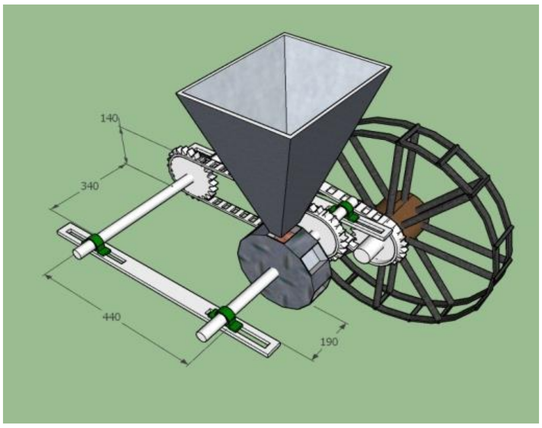

**Figure9.** *Power Transmission System*

## TESTING OF MACHINE

A 90m x 90m field located at the Federal University of Technology, Minna farm site was ploughed and harrowed. The field was then sub divided into plots of 30m x 30m. Turmeric rhizomes were obtained from National Root Crops Research Institute (NRCRI) Nyanya Sub Station, Abuja. The rhizomes were cleaned and sorted into 30mm, 45mm and 60mm lengths to determine the length which will give optimum performance. The planter was loaded with turmeric rhizome and then planted on the 30 m x 30m sub plots at three different operational speeds of 8km/h, 10km/h and 12km/h for each group.

A three-variable, three level factorial design ($N = 3^3$) provides the frame work for the experiment. The experimental design was a split-plot design according to the principle of factorial experiment. The three levels of speeds were assigned to the sub plot and the three levels of turmeric rhizome length were confounded to the split-plot. The data were subjected to Analysis of Variance (ANOVA) using expert design software and the following parameters were computed:

### Miss Index

Misses or skips are created when seed grooves fail to pick up and deliver seeds to the delivery funnels. Misses are counted along a randomly selected 15m length of each planted row with the covering devices removed. The missing percentage is presented by an index called the miss index (MI) which is the percentage of spacing greater than 1.5times the theoretical spacing (katchman and smith, 1995).

$$MI = \frac{n_s}{N} \times 100 \qquad (11)$$

Where: ns = number of skips

N = Total number of spacing

**Field capacity of Planter:** The field capacity of the planter is the total area of land that was covered. It is expressed as the area of field covered in given time and was obtained as follows:

$$C_M = \frac{A_f}{T} \qquad (12)$$

Where $C_M$ = machine capacity (ha/h)

$A_f$= area of field covered ($m^2$)

T = time taken (h)

## RESULTS AND DISCUSSION

### Miss Index

Table 1 shows the performance of the machine in terms of miss index. The result show that the miss percentage decreases with an increase in turmeric rhizome length. This observation does not agree with the findings of Singh and Gautam, (2015). The results of the planter show that there was no steady pattern in the increase or decrease of miss index with increase in turmeric rhizome length and machine operational speed. The highest percentage turmeric rhizome miss index of 35% was recorded for turmeric rhizome length of 30cm at machine operational speed of 10km/h whereas the lowest percentage turmeric rhizome miss index of 15% was obtained for turmeric rhizome length of 60cm at the machine operational speed of 12km/h. The reason for this trend is because shorter rhizomes fall out easily as more than one turmeric rhizome tends to fall from the hopper to the metering system.

**Table1.** *Effect of machine operational speed on miss index for different lengths of turmeric rhizome*

| Levels | Machine speed (km/h) | Percentage of miss index for different turmeric rhizome lengths (%) | | |
|---|---|---|---|---|
| | | 30 | 45 | 60 |
| 1 | 8 | 30 | 30 | 25 |
| | 10 | 35 | 20 | 15 |
| | 12 | 30 | 25 | 20 |
| 2 | 8 | 30 | 35 | 15 |

| | | | | |
|---|---|---|---|---|
| | 10 | 35 | 15 | 20 |
| | 12 | 30 | 25 | 20 |
| 3 | 8 | 35 | 25 | 20 |
| | 10 | 25 | 20 | 20 |
| | 12 | 35 | 30 | 20 |

The result of the analysis variance (ANOVA) indicates that the machine operating speed has significant effect on the miss index of the turmeric rhizome prototype planter (at $P < 0.05$) while the grading of the turmeric rhizomes into different length has no significant effect on the miss index (at $P > 0.05$).

## Field Capacity

Results of test carried out to evaluate the planter's field capacity with respect different operational speeds are shown in table 2. The field capacities of planters depend on the operational speed. The results show that increase in machine operational speed resulted in an increase in field capacity of the machine for all turmeric rhizome lengths which agrees with Khan and Moses, (2017). It was observed that the field capacity of 0.63-0.65ha/h was obtained for all turmeric rhizome lengths at the lowest operational speed of 8km/h, while the highest field capacity of 0.95-0.96ha/h was recorded for the various lengths of the turmeric rhizome at the highest machine speed of 12km/h. Furthermore, the best planting field capacity of the turmeric rhizome planter was obtained when the rhizome length of 45 cm was planted at the operational speed of 12km/h.

**Table2.** *Effect of machine speed on field capacity for different lengths of turmeric rhizome*

| **Levels** | **Machine speed (km/h)** | **Field capacity at different length of turmeric rhizome (ha/h)** | | |
|---|---|---|---|---|
| | | 30 | 45 | 60 |
| 1 | 8 | 0.64 | 0.65 | 0.63 |
| | 10 | 0.80 | 0.83 | 0.84 |
| | 12 | 0.96 | 0.96 | 0.95 |
| 2 | 8 | 0.65 | 0.63 | 0.66 |
| | 10 | 0.84 | 0.82 | 0.84 |
| | 12 | 0.95 | 0.96 | 0.94 |
| 3 | 8 | 0.66 | 0.63 | 0.64 |
| | 10 | 0.82 | 0.83 | 0.84 |
| | 12 | 0.94 | 0.95 | 0.96 |

## CONCLUSION

The machine was successfully constructed and evaluated. The performance evaluation of the machine was carried out to assess the miss index and field capacity of the planter at three levels of operational speed of 8, 10 and 12 km/h and three levels of turmeric rhizome length of 30, 45 and 60 mm.

The machine operating speed has significant effect on the miss index of the turmeric rhizome prototype planter ($P < 0.05$) while the grading of the turmeric rhizomes into different length has no significant effect on the miss index. There was no steady pattern in the increase or decrease of miss index with increase in turmeric rhizome length and machine operational speed.

The field capacity of the planter mainly depended on operational speed. The size of the cane seeds (diameter and length) did not affect the field capacity of the machine. The highest capacity of 0.96 ha/h was recorded at the highest operational speed of 12km/h while the lowest field capacity of 0.63 ha/h was recorded at the lowest machine speed of 8km/h.

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